Image Cover Sheet 98-01222

CLASSIFICATION	SYSTEM NUMBER
UNCLASSIFIED	508030

TITLE

HUMAN FACTORS OF CC-130 OPERATIONS. VOLUME 4: TRAINING SYSTEMS KNOWLEDGE

System Number:

Patron Number:

Requester:

Notes:

DSIS Use only:

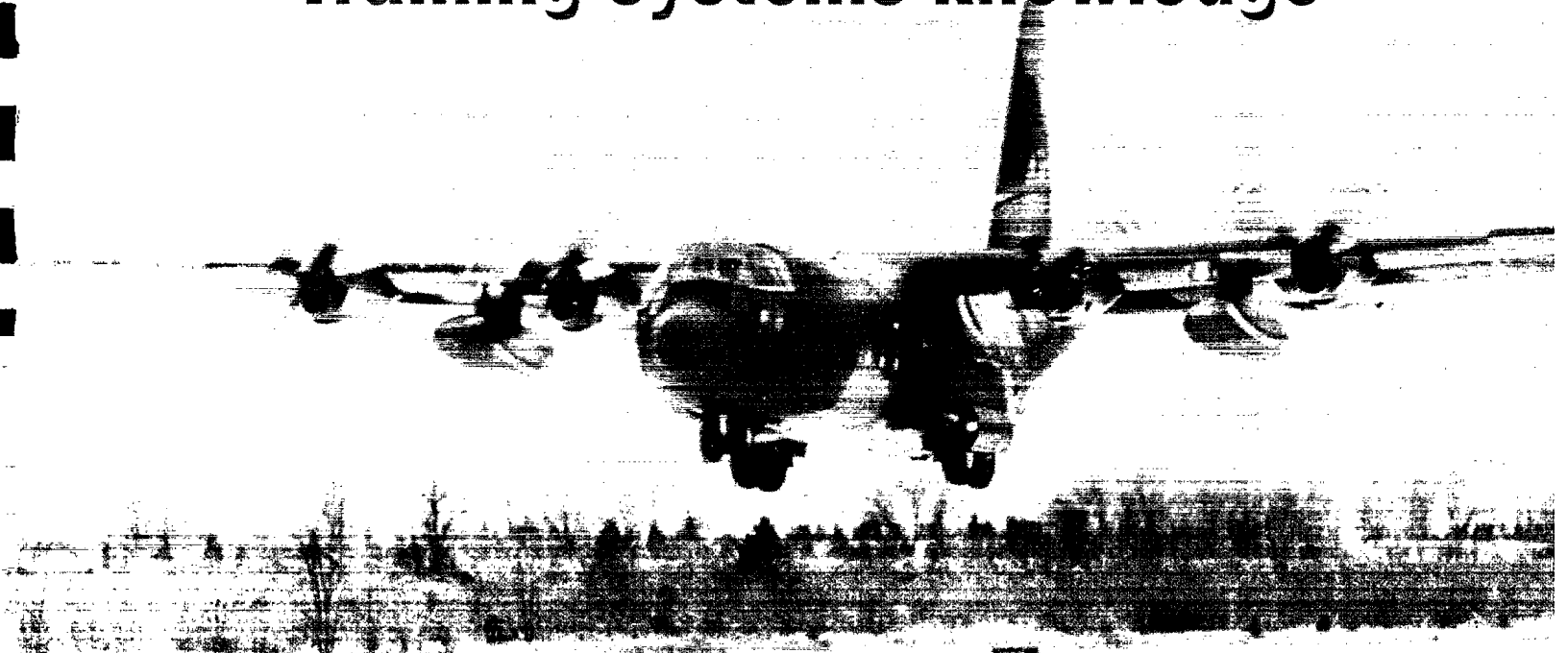
Deliver to:

National Défense
Defence nationale

DCIEM Report No. 98-R-17

Human Factors of CC-130 Operations

Volume 4: Training systems knowledge



D.W. Jamieson

Defence and Civil
INSTITUTE OF ENVIRONMENTAL MEDICINE

Canada

February 1998 DCIEM No. 98-R-17

HUMAN FACTORS OF CC-130 OPERATIONS

VOLUME 4: TRAINING SYSTEMS KNOWLEDGE

D.W. Jamieson

Defence and Civil Institute of Environmental Medicine
1133 Sheppard Avenue West, P.O. Box 2000
Toronto, Ontario
Canada M3M 3B9

© HER MAJESTY THE QUEEN IN RIGHT OF CANADA (1998)
as represented by the Minister of National Defence

© SA MAJESTE LA REINE EN DROIT DU CANADA (1998)
Défense Nationale Canada

DEPARTMENT OF NATIONAL DEFENCE – CANADA

EXECUTIVE SUMMARY

The following recommendation, made in the June 1996 briefing to the Commander, Air Transport Group (ATG), served as the impetus to the work.

- Raise the overall level of systems knowledge among ATG aircrew by developing teaching aids and courses to accelerate the acquisition of knowledge and to compensate for lowered fleet experience levels through advances in training program delivery.

In this Volume, systems knowledge training is first placed within a general risk management scheme as an overall causal framework for securing safer and more effective operations within the CC-130 community of 1 Canadian Air Division (1 CAD). Systems knowledge acquisition is seen to be a latent risk factor, operating both as a precondition/psychological precursor of risk at the level of the individual, and as a systemic line management deficiency at the level of the organisation. Formal evaluation of the state of systems knowledge fleet-wide is needed to provide feedback to the organisation in its attempts to manage latent risks.

Current systems knowledge training practices within the organisation are reviewed next, including past assessments of the need for modernisation of training. It is concluded that while current training practices are sound, thorough, and professional in execution, there remains room for improvement because downsizing and experience loss have impeded the ability of 8 Wing, Trenton, to achieve training modernisation .

A selected review of best training concepts and practices is presented, based on the recent literature on education and training. Those concepts best suited to the CC-130 training environment are identified. The key areas covered include:

- the importance of life-long learning;
- a just-in-time knowledge-to-skill training model;
- problem-based (i.e., case-based), self-directed learning;
- effective use of interactive multi-media for training at the Operational Training Unit (OTU), for on-the-job training (OJT) and self-study;
- methods for the development of superior mental models of aircraft systems and their operational interdependencies; and
- the need for evaluation at three levels: trainee self-evaluation, OTU/OJT formal student evaluation, and organisation-wide monitoring and evaluation.

A set of recommendations is then presented, for value-added training system improvements in the area of aircraft systems knowledge acquisition. These recommendations are based on the best adaptable training practices that can be delivered within current organisational restraints, including:

- distributing more formal, detailed skill training to the Squadrons, while keeping conceptual mental model building the focus of the OTU;
- teaching the **A**wareness **I**mplications and **P**lanning (AIP) model as a conceptual approach at an early stage and throughout training so that it becomes habitual;

- using more case-based teaching, supported by video simulations of good as well as poor systems handling, making sure that aircraft system interdependencies, and the need for implicational thinking and pre-planning to deal with these, are illustrated;
- forging partnerships in the world-wide CC-130 community to build a library of cases quickly;
- leveraging the Smart Board software pieces — deploy the Smart Boards at both the OTU and OJT within the context of both problem-based learning and self-study, combining them with a case-based method, and intelligent tutoring for self-directed, continuous performance improvement — build the tutor to provide feedback that will develop pilots' abilities for objective, independent self-evaluation of the state of their systems' knowledge (i.e., meta-knowledge) and motivate self-initiated learning;
- develop appropriate standards and evaluation tools for this type of training;
- conduct formal evaluation studies to document the efficacy of these value-added improvements; and
- create a non-jeopardy database to monitor and track fleet-wide the development of superior systems knowledge.

The Volume concludes with a summary of the deliverables, the implications for implementation that are discussed throughout, and the resource requirements implied by adoption of these recommendations.

CONTENTS

EXECUTIVE SUMMARY i

INTRODUCTION 1

SYSTEMS KNOWLEDGE IN THE MANAGEMENT OF RISK 3

AS A PRECONDITION/PSYCHOLOGICAL PRECURSOR OF RISK 4
AS A LINE MANAGEMENT DEFICIENCY RISK 4

REVIEW OF CURRENT TRAINING 7

REVIEW OF 426 SQUADRON TRAINING 7
HYPHER'S STUDY OF CC-130 PILOT TRAINING MODERNISATION 8
REVIEW OF EDUCATION AND TRAINING LITERATURE 10

RECOMMENDATIONS 25

CONCLUSIONS 27

REFERENCES 29

ACKNOWLEDGEMENTS 33

APPENDIX 1: LISTING OF RESOURCES 35

INTRODUCTION

This is Volume 4 of a six volume series describing the outcome of a human factors study into CC-130 operations (see References [1-5] for details of the remaining documents in this series). In this Volume the issue of needed improvements to the training of systems knowledge is addressed. After reviewing the reasons why this was identified as an area needing improvement, such training is placed within an overall risk management framework for securing safer and more effective operations within the CC-130 community. Current systems knowledge training practices within the organisation are then reviewed, including past assessments of the need for modernisation of training. Following this, a selection of best training and education concepts is reported, based on the recent literature on education and training, showing which of these concepts are best suited to the CC-130 training environment. This leads naturally to a set of recommendations for value-added training system improvements in the area of aircraft systems knowledge acquisition. It is argued that there is a need to quantify, with suitable empirical documentation, the magnitude of these training improvements after deployment, and to monitor, fleet-wide, the evolving norms regarding pilots' systems knowledge. This would provide feedback to the organisation in its attempts to manage latent risks. Implications for implementation of these ideas for both the Operational Training Unit (OTU) and for On-The-Job Training (OJT) are drawn out and reported as to complete the analysis. Finally, the resource requirements implied by such changes are enumerated.

The following recommendation made in the June 1996 briefing to the Commander, Air Transport Group (ATG), served as the impetus to the work.

- Raise the overall level of systems knowledge among ATG aircrew by developing teaching aids and courses to accelerate the acquisition of knowledge and to compensate for lowered fleet experience levels through advances in training program delivery.

This recommendation resulted from the observation of inadequate in-depth aircraft systems knowledge demonstrated by several pilots in the Crew Behaviour Assessment Group (CBAG) behavioural measurement validation study [6]. These pilots had difficulty recognising, diagnosing, or ameliorating some of the aircraft systems failures incorporated into this event-based scenario. While a few limited observations do not make a fleet-wide trend, these observations were embraced by ATG as perhaps typical of a more general problem — at least on an intuitive and anecdotal level since adequate measures of systems knowledge proficiency do not currently exist that would document fleet-wide trends in this type of expertise.

SYSTEMS KNOWLEDGE IN THE MANAGEMENT OF RISK

Within Reason's [7] systems approach to risk management, adopted as a framework for the activities of the CC-130 study team (see Volume 1 of this series for a more detailed discussion), the acquisition of aircraft systems knowledge can be seen as occurring relatively early in the chain of organisation-wide activities in which 1 Canadian Air Division (1 CAD) engages. A lack of adequate and appropriate knowledge of aircraft systems can therefore be conceptualised most generally as a latent, as opposed to an active, failure in the accident sequence. Such lack of knowledge can be classed as occurring within two of the risk management system states earlier defined, namely 'Preconditions' and 'Line Management Deficiencies'. These two states correspond to control loops 3 and 4, respectively, of Volume 1, Figure 4 (repeated below, as Figure 1, for convenience).

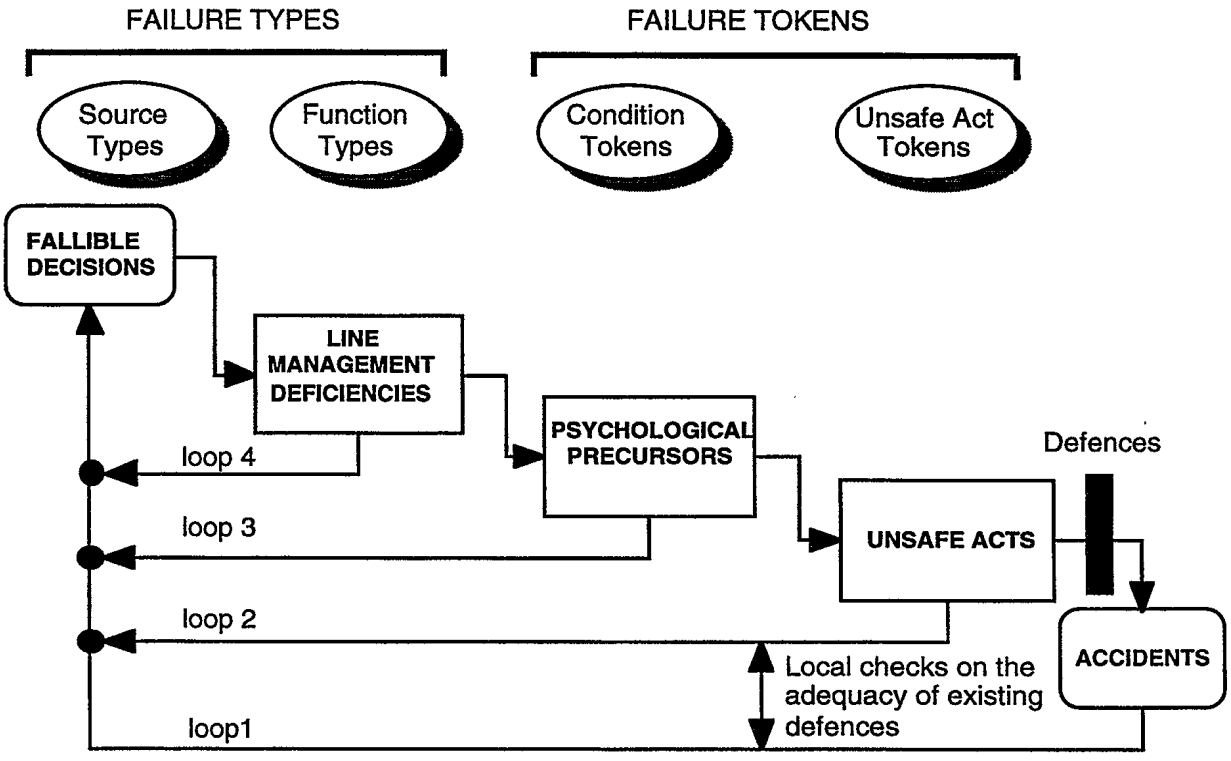


Figure 1. *Feedback loops and indicators for the management of system safety* (after Ref. [7], Figure 7.9).

As a Precondition/Psychological Precursor of Risk

Inadequate systems knowledge, possibly caused through a variety of factors such as experience loss, or an erosion of training or standards, sets a precondition for failure because key cockpit decision makers (Aircraft Commanders or ACs) are inadequately skilled to meet, with sufficient alacrity, common aircraft systems challenges, outages and failures. Unsafe acts become more probable in a context of lowered or inadequate systems knowledge, and the more unsafe acts attributable to this source, the more likely this latent failure may eventuate in accidents when 1 CAD's defences-in-depth are repeatedly tested due to this cause.

It is obvious to aircrew (anecdotal evidence; see also the study of dimensions of captaincy in Volume 5 of this report) that a key dimension of leadership and captaincy in terms of both safety and production, is a high degree of systems knowledge proficiency. No matter how it is initially imparted, or later developed, embellished, and translated into skill, systems knowledge is a necessary pre-condition for the prevention of unsafe acts, and for the recovery from them as well. In the terms used previously [6, 8], pilots must have a well-articulated and organised mental model of each aircraft system and of each system's interactions with other systems.

These mental models are complex cognitive representations of the various systems' functions. Such cognitive representations allow heightened abilities for:

- perception and situational awareness;
- judgement;
- implicational/inferential thinking;
- pre-planning; and
- dynamic decision making.

Each of these functions of aircraft systems mental models allows for faster and more accurate assessment and action, buying valuable time in the Information Processing (IP) model[1] trade-off between the time required to do what must be done and that time available to do it [9]. In addition, superior knowledge representation of systems implications allows for preplanning and decision making that can 'buy time' when necessary, again insuring that the IP Model ratio does not exceed one. Under such conditions of superior aircraft systems proficiency, advanced systems knowledge representations become skill-like in their implementation. This is a simple description of the preparedness that comes with high skill levels; well-developed mental models about aircraft systems contribute to more effective and efficient information processing about those systems, as well as to a reduction in workload stress and an improvement in both safe and efficient flight performance in real-time operations. Simply put, this state of mental model functioning can be taken as a definition of expertise with aircraft systems.

As a Line Management Deficiency Risk

The development of superior systems knowledge that will ensure both safe and efficient flight performance can be, and is, imparted at many levels, and at many time points in the overall training of CC-130 pilots. One obvious place for intervention, as well as for monitoring systems knowledge to provide feedback to the risk control system, is at 426 Squadron — the OTU. In the context of lowered fleet-wide experience levels (see Volume 1 of this report), more effective and efficient delivery of systems knowledge training can serve to compensate, at least in some

[1] The IP model was one of the theoretical positions that guided this study (see this report, Volumes 1 and 5). The IP model claims that performance, error production and perceptions of workload are all driven by the time pressure (i.e., the ratio of time required to time available).

measure, for a loss of expertise. It was a goal of the CC-130 study team to identify those teaching philosophies, approaches, methods, materials, delivery systems etc., that can best add value to an already redoubtable training effort at 426. In leveraging even further the many solid approaches to training as well as training technologies currently in place at the OTU, it is hoped to be able to recommend improvements to training delivery that will push trainees more quickly up the learning curve toward high proficiency. It is also hoped to be able to document the efficacy of these improvements with suitable empirical evidence regarding their effects, in the form of formal evaluation studies. In addition to demonstrating the efficacy of the proposed improvements, these studies will serve as a model for the kind of evaluation studies needed by the organisation to track the state of systems knowledge , as pilots exit the various OTU courses.

In recognising the limited exposure that pilots have to 426 Squadron, components of training outside the OTU, that are in need of amplification or introduction, are also foreseen. In particular, OJT at Squadron is also a focus of the study team's recommendations. The distribution of superior training techniques to all levels and kinds of training exposure is the best way, it is considered, to achieve a fleet-wide improvement in systems knowledge. As in the case of the flight school, adequate evaluation, standards, and monitoring must be put in place for OJT that will allow multiple-source feedback on the normative state of system knowledge performance fleet-wide. This feedback will inform the risk management system at a deep level (corresponding to control loop 4 in Figure 1) of potential, or latent, failure in the area of knowledge of aircraft systems. Such a monitoring system is particularly important and timely given the near-term upgrade to the semi-glass cockpit for the CC-130, because past research has shown that systems interdependencies in such aircraft exacerbate the difficulty of training [10].

REVIEW OF CURRENT TRAINING

In Phase I of the CC-130 study, anecdotal evidence of inadequate aircraft systems knowledge among some crew participants from the crew performance validation study was observed, noted and reported to ATG [6]. In Phase II, activities were directed toward identifying and recommending mechanisms for the accelerated acquisition of systems knowledge both within formal and on-the-job training. Because it was Aircraft Commanders (ACs) who exhibited the clearest instances of lack of systems knowledge in the CBAG study (though it is recognised that it is likely only a very small minority of ACs that is not currently meeting appropriate standards), that focus was on the acquisition of systems knowledge among ACs at various levels of training. The current Phase II activities were therefore directed toward:

- conducting a review of current 426 training system methods, materials, and practices;
- conducting a selected review of the education and training literature — both theory and current practices; and
- making recommendations for value-added improvements to the training system in terms of effectiveness, efficiency, and evaluation.

Review of 426 Squadron Training

The review of 426 Squadron training philosophy and regimes included interviews with trainers and course developers, reviews of written course materials and limited attendance at some courses. The focus was on conversion training and the upgrade course, since it was pilots' (particularly ACs') system knowledge more than systems knowledge at any other crew position that most directly affected the outcomes of the flights we observed in the validation study.

This review confirmed that some excellent training resources exist at the Squadron currently for the acquisition of systems knowledge, and that a starting infrastructure exists to expand upon these already-excellent offerings. It is considered that current 426 Squadron training is well-grounded in education/training theory, is both comprehensive and thorough in coverage, and is professional in execution. Future efforts at adding value to this system should use these existing elements as a base for what would be characterised as a small to moderate re-engineering of current instruction. However, there are areas that can be leveraged further, some that would be classed in the area of training effectiveness, and some in the area of training efficiency.

Particular strengths observed in the training of systems knowledge include:

- clear, lesson-specific instructional goals;
- comprehensive course materials;
- effective examples and scenarios;
- use of a multi-tiered approach (i.e., lectures, mock-ups, part-task simulations, full-motion simulations, etc.);
- effective use of cases;
- presence of experts in the classroom to address problems/questions; and

- use of smart board technology as the mechanism of instructional delivery in certain instances (i.e., fuel, and hydraulics at present).

Areas of potential improvement at 426 Squadron, and for OJT, that were identified include:

- striking a new relative balance between the conceptual content and the detail communicated about systems;
- use of OJT/Squadron Standards Officers to continue the conversion of knowledge to skill in a way consistent with and co-ordinated by trainers;
- an operations-specific training needs assessment conducted at the various Squadrons to tailor some training toward customers differing in role requirements;
- updating materials and examples;
- use of even more facilitation-type teaching with case study examples;
- explicit methods for developing superior mental models of aircraft systems that include awareness, implicational thinking, planning, and decision making regarding those systems;
- explicit methods for developing mental models of aircraft system interactions;
- opportunities for training, developing and exhibiting systems knowledge and systems knowledge-relevant decision making in dynamic, more realistic, event-based scenarios (low- to high-fidelity);
- completion of the outstanding smart boards for systems not yet represented and taught in this mode;
- increased functionality of the smart boards (e.g., to allow and stimulate implicational thinking about systems);
- improved, formal evaluation and organisational feedback at every stage of training; and
- provision of tools and motivation for career-long self-study, student feedback and the development of self-evaluation skills.

The review of systems knowledge training was done in conjunction with a review of current education and training practices. The latter served as a filter through which to view current CC-130 training practices. Before turning to this review, it is instructive to compare the CC-130 study group's independent assessment of systems knowledge training circa 1997, with one conducted by ATG in 1990. In some respects the review and recommendations made some 7 years ago strongly foreshadow the position taken in this Volume.

Hypher's Study of CC-130 Pilot Training Modernisation

In 1983, Mr. Peter Hypher, then Operational Research Advisor, reviewed the CC-130 training systems at the Operational Training Unit as part of the Commander ATG's initiative to modernise the pilot and aircrew training systems [11]. He updated his review in 1990, under contract to the Operational Research and Analysis Establishment [12]. Both reviews distinguished between the concepts of cognitive and psycho-motor skills acquisition, emphasised the need for a progressive learning approach, and sought to encourage the adoption of progressive training aids.

Hypher's main arguments were:

- that learning of cognitive and psychomotor skills within ATG took place largely in isolation and needed to be integrated/alternated all along the continuum from the OTU Conversion, to OJT, to Upgrade; and
- that the ideal training system would incorporate training aids ranging along a continuum from textbooks and lectures, to computer-based training (CBT) lessons, to part-task trainers (PTT),

to cockpit procedures trainers (CPT), to the full motion simulator (Sim), and finally to the aircraft.

By 1990, he saw CBT as desirable and feasible and spent much of his report reviewing and recommending it as the best method for transmitting basic knowledge and training.

Since 1990, several aids have been added to the training system, including the cockpit mock-up (CMU) arising out of the CC-130 Avionics Update Programme (AUP), and the Smart Board systems packages (fuel and hydraulics delivered, with remaining systems on order: electrics, propellers, etc.), that go a long way toward meeting the recommendations Hypher made. Importantly, many of Hypher's observations with regard to the needs of the training system hold as true today as they did 7 years ago. Organisational stresses in the form of downsizing and fleet-wide pilot experience loss have prevented 426 Squadron's ability to modernise its training as rapidly as hoped.

When Hypher's arguments are applied to the issue of systems knowledge acquisition, many of the assertions and recommendations are accepted, but issue is taken with several points too. Without exhaustively reviewing his main contentions (which stand in his own companion document), the areas of basic agreement with his training system vision, and areas where there are differences, are summarised below.

It is agreed with Hypher [12]:

- that the present OTU systems knowledge treatment "...over-teaches the technical detail..." (p.17);
- that there needs to be more emphasis on "...good airmanship and airspace awareness initially than on technical detail..." (p. 22) at the OTU;
- that the OTU tends to teach "...ten years of systems failures..." (p. 3) in a few days at the Conversion course and that this overloads the student;
- that there is a need for a progressive learning approach in the area of systems knowledge acquisition (p. 3);
- that there is a need for progressive training aids to teach systems knowledge (p. 19);
- that the present training system consists (still) of too much chalk-and-talk with regard to systems knowledge (p. 7; though this is changing with the introduction of each new Smart Board module); and
- that a rating system be introduced to assess the training value for each aircraft system of each operational training flight (p. 77).

His call for the introduction of self-paced study is also accepted, though there are differences on the best mechanism for this. Hypher recommended traditional CBT, which was state of the art at the time, and this represents the main area of apparent discrepancy between the recommendations of the CC-130 study team and those of Mr. Hypher. While it is true that traditional CBT has many advantages over lectures, including shortening systems knowledge acquisition times and bolstering knowledge retention, the developmental efforts and costs attached, estimated as taking anywhere between 250 to 800 person hours of preparation per hour of CBT instruction, and as costing between $15,000 to $30,000 per hour of final CBT product, are prohibitive. Moreover, these sorts of estimates are for classical CBT, which amounts in many cases to expensive page-turning software of largely text-based material. To fully realise the advantages of sound, video, animation, and simulations within a classical CBT environment would add incrementally to these costs.

ATG has not in the past chosen the classical CBT option for training systems knowledge, and in hindsight the study team concurs. CBT is not the appropriate alternative even at this time,

especially in light of the development of another (but relatively less) cost-intensive vehicle for instruction — the Smart Board CDs. These can powerfully substitute for CBT — indeed, they are a form of it — while at the same time, it is believed, achieve considerable training efficacy (it is argued below that this training efficacy should be documented empirically via formal evaluation research using objective performance measures, evidence that will quantify the Smart Boards' effectiveness and increase their marketability in other C-130 communities).

Recent advances in authoring systems for multi-media training suggest that using commercially available authoring software may now be viable for the creation, maintenance and revision of multi-media courseware for the CC-130. This flexibility in design and the ability to amend lesson plans has been, heretofore, largely lacking among CBT packages. These can now be usefully and easily employed as courseware generators among multi-media literate trainers. It is recommended that caseware and courseware be built, placing as their centrepieces, the Smart Board system simulator module. Emphasis on preplanning and decision making will be manifested as lesson objectives that surround, and are placed 'on top' of the basic Smart Board capability. Were Mr. Hypher to have been writing today, given his stated recommendation to integrate sound, video, and simulation within classical CBT, it is suspected that he would in agreement as to the training potential inherent in the Smart Board systems.

Another key area of disagreement in the learning model adapted for the current review of CC-130 training, as compared with Hypher's own recommendations, is his statement that conversion training should emphasise "...'how to operate systems' rather than 'how they operate'..." (p. 129). It is believed that a sound conceptual basis — understanding how and why the system operates as it does — provides a key knowledge structure within which technical detail and skill can be incorporated and retained. Enough *how to* operational knowledge must be imparted to allow aircrew to contribute as useful team members upon exiting the conversion course, but a sound conceptual understanding is a necessary pre-condition for differentiated, integrated, and retrievable systems knowledge. This is especially the case as the issue (increasing in importance with the Avionics Update Project [AUP]) of interconnected systems functioning [13] is broached. Situational awareness, implicational thinking, pre-planning ability, and decision making are all facilitated by a sound mental representation of systems' causal interactions.

One of Hypher's stated reasons for suggesting CBT, was to secure self-study opportunities and access for students. Digital compression and other computer technology advances since the time of his writing now make network-hosted, fully interactive multi-media CBT with simulation components realisable in the near term as a tool for systems knowledge training. The Smart Boards represent software pieces that can be fairly easily adapted to be self-paced, self-directed distance learning applications, concurring with and delivering Hypher's earlier vision for career-long currency maintenance and performance improvement.

Review of Education and Training Literature

Several of the areas for improvement, identified above, were inspired as a result of a selected review of the current literature on education and training. Those trends, themes and principles judged most pertinent to CC-130 pilot training are summarised below as six main points. At each point the principle involved is reviewed, what is believed to be its best application within the CC-130 training environment is described, and the implications that adoption or further extension of the training approach/principle would have are outlined. Recommendations are summarised only after describing all the points in order to avoid redundancy, because many of the themes are strongly inter-related. Resources that may prove useful in future implementation are referenced, and listed in the resource appendix attached (Appendix 1).

There are six key themes involved in this review. These range from motivational factors that will ensure more effective training and an emphasis on conceptual models, all the way to specific ideas concerning appropriate self-paced multi-media tools that will simultaneously improve training efficiency, effectiveness, and evaluation. The six themes to be described are.

1. The Importance of Life-Long Learning.
2. A Just-in-Time Knowledge-to-Skill Training Model.
3. Problem-Based (i.e., Case-Based), Self-Directed Learning.
4. Effective Use of Interactive Multi-Media for OTU/OJT and Self-Study.
5. Methods for the Development of Superior Mental Models of Aircraft Systems and their Operational Interdependencies.
6. The Need for Evaluation at Three Levels: Trainee Self-Evaluation, OTU/OJT Formal Student Evaluation, and Organisation-Wide Monitoring and Evaluation.

The Importance of Life-Long Learning

Life-long learning is a concept, of great currency value of late, in educational theory and practice [14, 15]. Educators and trainers have long recognised that the pace of technological invention and change means that the half-life of most knowledge is limited. In an age of rapid advancement, it becomes requisite that practitioners in every field keep constantly in tune with the latest trends and developments in their areas of expertise. Responsibility for the pursuit of continuous education and performance improvement throughout the career- and life-span now vests with individuals as well as the training arms of organisations. Life-long learning is the way of the future for everyone, and its need is already here.

The concept of life-long learning is viewed as being essentially a motivational one. Eventually, through the development of assessment instruments that will allow the organisation to carefully identify, screen, and select those candidate pilots in possession of both a natural propensity toward self-improvement via self-motivated study and a natural heightened recognition of the need to stay current, 1 CAD will be able to select individuals who come bearing the right, 'life-long learning', stuff. However, such diagnostic measures of personal motivation and selection are not yet in existence, and so steps that are systemic and situational in nature must be put in place that will motivate aircrew toward self-improvement at the same time as giving them the kind of tools and affording them the kind of learning environment where motivated self-study can flourish early on — and be maintained throughout the career-span. In other words, 1 CAD must create, even more than it has already largely successfully done, the means, motive and opportunity for life-long learning.

There are larger issues of organisational structure, career paths, incentive systems, organisational commitment and the like that will need to be broached to ensure the success of instilling a philosophy of life-long learning [16]. This Volume will focus on tools for self-directed, continuous improvement rather than on these larger organisational issues. It is believed that the kind of balanced training model proposed (see next section) will make training more enjoyable, (even) more respected, and more motivating than it is currently, in keeping with the kind of role (and status) within the organisation that the training system must occupy.

Implications. Occupational environments that promote life-long learning must support such learning with proper tools and aiding. Limited teaching budgets suggest that continual improvement and education is done most cost-effectively if the student assumes major responsibility for their upgrading via self-study. In the area of systems knowledge acquisition, this suggests that appropriately gauged self-study packages be available to pilots on an on-going basis. This also implies that experts be available for consultation in support of self-study, and that software, for example, be available to provide an appropriate degree of 'help' when needed in the

absence of such experts. Help can range from the provision of indexes and glossaries during self-study all the way to intelligent tutoring systems (see below). Since most of these self-study materials are likely to be computer-based (i.e., software), this also implies some investment in pilots' computer literacy early on in their training to maximise their self-study and life-long learning potentials.

A Just-in-Time Knowledge-to-Skill Training Model

Effective training starts with the conveyance of knowledge, by which it is meant that a conceptual understanding of the subject based on theory and examples is laid down, and through practice this knowledge becomes appropriately skill-based. Simple principles of knowledge acquisition suggest that a strong conceptual grounding, or infrastructure, is necessary in the knowledge acquisition process. Later detailed understandings are best learned and retained when they can be assimilated to an existing conceptual 'scaffolding' (i.e., assimilation of knowledge is always easier than accommodation).

In the present instance, this conceptual scaffolding can be understood in terms of solid, cognitive schemata, or mental models, of aircraft system functioning. These mental models promote higher order cognitive processing, such as inference, reasoning, trouble-shooting, etc., because they represent not just what a system does, but how and why. Once a strong conceptual mental model is in place, the assimilation of details in practice is an efficient process. It is considered that some training benefits may accrue if the limited exposures pilots have to 426 Squadron is even more concentrated than at present on improving this conceptual understanding (i.e., laying the basis for superior cognitive representations), while OJT continues to concentrate on the assimilation of details and the development of skill. Over-teaching of detail at the OTU is not a wise use of limited ground school time.

The latter point relates to the important issue of the timing of learning. Learning is maximised when concepts are acquired 'just-in-time', that is, when they are actually needed in practice; knowledge that is transmitted but is unrehearsed quickly atrophies (as anyone who has taken a course but not applied it for several months will attest). 'Just-in-time' is a term that strongly implies skill transmission at the squadron operational level. Therefore, careful consideration must be given to articulating when it is that different kinds of knowledge are optimally acquired within the entire training system. An over-emphasis on detail to the detriment of conceptual understanding at 426, when this is more appropriately transmitted at Squadron, will not produce long-term retention.

It is important to note that for a conceptual scaffolding to work, it must be supported by tools that allow strong conceptual understanding to be stimulated at OTU and strong knowledge-to-skill conversion to occur during OJT. The Smart Boards provide just such a ready training tool/aid for the development of stronger conceptual understanding in the form of the schematic visual representation of aircraft systems presented (usually) in the upper half of their screen displays. The ability of the student to manipulate this schematic interactively, and to receive feedback about the results of their control actions, promotes a strong conceptual understanding of how and why the system operates as it does. In addition, the simulation capabilities of the Smart Boards, in combination with appropriate cases that teach operational skill in the relevant contexts, and at the pertinent times, allow the tool to achieve the aim of knowledge-to-skill conversion as well.

Implications. The division of training labour suggested by this re-balanced training model implies an increased reliance on skill development at the Squadrons, which, in turn, entails a somewhat higher level of support for training at the Squadron level than currently exists. This support should come in the form of transmission of the Smart Board learning tools to all squadrons, accompanied by training of squadron Standards Officers in their facilitator role within

the scheme of problem-based (case-based), self-directed learning (see next section). Central co-ordination, monitoring, and evaluation of the entire training model, when delivered in this way, is required, and should be based most appropriately at the training Squadron.

Problem-Based (i.e., Case-Based), Self-Directed Learning

One influential mechanism for fostering a stance on education that can be described as 'life-long', at the same time that it imparts strong concept building, is the use of problem-based, self-directed learning [15, 17-19]. Because there are many ways to implement what is deemed to be a 'problem-based' and 'self-directed' approach in education, care should be taken in defining these terms. When this is done it will be discovered that not all elements of the approach lend themselves to easy adoption in the military training environment. However, carefully pruned, the techniques of this approach can be usefully applied both to the OTU and to OJT at the operational squadron levels. This approach is summarised, and an attempt is made to show how it can be usefully adapted at the OTU and for OJT.

Problem-Based Learning. Classically, problem-based learning as been described as involving the presentation to students of specific real or simulated case studies in a particular field that present a problem or challenge requiring solution. It is contended that via such 'situated learning' new material is better understood and retained, because it is learned in concert with environmental cues to be encountered in the real situations in which the learning will be relevant [20].

The cases are meant to provide a springboard for learning, and, importantly, for learning about learning. Typically directive forms of instruction such as the chalk-and-talk lecture are not used with this approach and the instructor's role is re-defined as being one of an intellectual shepherd, mentor or facilitator. Students work both individually and in small groups, to define actively the issues and questions to be addressed, the tasks to be done, and the information to be discovered or recruited. In this way the method is self-directed in addition to being problem-based. After discovering on an individual basis the information to be used, trainees then work together with the information they have accumulated to synthesise, discuss, and integrate it, and to make final recommendations about the problem solution.

Because problems are multi-determined and multi-faceted, the information sought usually must be extracted from a variety of disciplines and sources, and in a variety of ways. It is contended that this is a learning challenge and intellectual environment that is more representative of the real-world problems and performances expected of employees in almost every field once they graduate from training. And it is also asserted that such 'contextual learning' (i.e., learning as needed, just-in-time, and in the context where it will later be applied) makes the learning more enjoyable and more effective as well.

The group-based learning portion is integral to the process, as it is a central 'method of work', a method again often representative of the real world group working environments in which trainees will spend most of their professional lives [21, 22]. Thus, the knowledge gained about group dynamics in the group-centred part of this inquiry/learning process also transfers to the real work environment, where people are expected more often to perform in groups than alone (especially in highly technical work environments).

Co-operation and teamwork skills are fostered from initial training onward when group-based learning is integrated into the method of instruction, as people become aware of such things as:

- how to manage differential ability;
- how to contribute both to teamwork and taskwork;
- how to participate in others' learning;

- how to read one's own and others' emotional reactions;
- how to build trust;
- how to manage and resolve conflict constructively;
- how to give feedback to one another usefully and sensitively;
- how to manage difficult people; and
- how to instil as the key motive of team life the performance needs of getting the job done safely and effectively, rather than letting fear and competition drive human relations and team performance in either the training or real world environment.

Self-directed, problem-based learning is usually a new mode of learning for new inductees and as such, care is taken at the outset to provide training to trainees in the method of training itself, so that students understand the approach and their responsibilities within it. During this initial training trainees are engaged in learning how to learn.

Trainers also often need to be trained in the mode of facilitation required, which is usually quite different from their accustomed roles as 'experts professing'. They must learn in explicit terms how to help students learn how to learn. Trainers are asked to set cases, encourage and guide trainees without forcing or directing, provide a role model of critical thinking and critical self-examination, and assist group members in self-evaluation.

Trainers are also responsible for the evaluation of each member of the group and for shepherding group processes where necessary. Evaluations can be formal and on-going — conducted at the end of each session — or can be performed more infrequently at mid- and end-of-course. And of course, objective performance standards still serve as essential benchmarks of knowledge proficiency against which hard performance evaluations can be measured.

Everything in this approach is directed toward making the student responsible for their own learning and to set patterns and habits of learning suitable to their needs. This method of operation should be employed continuously throughout their professional career. However, it is important to note that while self-directed, learning is neither self-willed nor self-indulgent in this regime. Clear expectations for training, training standards and performance objectives are set and met. While the system of learning delivery is intended to be flexibly adapted to individuals' learning styles, what is not open for negotiation is the requirement to produce training outcomes of effective and efficient subject matter knowledge and proficiency. Therefore, the approach is self-directed and student-centred from the point of view of the training delivery mechanism, but the programme itself is not self-directed. Considerable guidance and modelling of best-learning practices is one of the key elements that trainers must provide in their re-defined role, and the course content is theirs to set as they see fit. This, in summary, is the 'how' of problem-based learning as it is currently conceived and practised.

Overview of Domains of Knowledge in Problem-Based Learning. The 'what', or content, resulting from this approach is usually divided into three intended domains of impact.

1. A knowledge base is grown: Knowledge consists of both facts and concepts. The problem-based learning approach tends to emphasise the development of sound conceptual understanding and models within which to organise facts (i.e., conceptual scaffolding), as well as the knowledge of how to gain access to specific information as required. This places it in keeping with the training model proposed for the OTU, wherein a greater emphasis on conceptual understanding is recommended than is currently practised.

2. The second domain of learning is skill: In this case this will include not only systems operational skill, procedural skill, and psychomotor skill, but also:

- critical appraisal skill, such as system situation awareness, the application of judgement, a questioning attitude, the ability to solicit and weigh evidence (like the quality of current flight data), system diagnostic and trouble-shooting skill, etc.; and
- learning skills, such as the ability to self-identify deficiencies in one's own systems knowledge, the ability to correct deficiencies, knowledge of resources available to correct knowledge deficits, and understanding the importance of constantly renewing one's base of knowledge (i.e., motivated remediation).

3. Finally, problem-based self-directed learning behaviours: This is a third kind of domain knowledge — namely the acquisition, development and maintenance of personal qualities and attitudes appropriate to the profession's roles and tasks. This knowledge includes:
   - team leadership and followership skills;
   - mentoring skills modelled from the examples provided by the intellectual shepherds — the trainers; and
   - a motivated attitude of life-long learning — continual self-improvement.

Thus, in total, the process is intrinsically oriented toward the kind of personal and teamwork development required of left-seaters in their professional conduct inside the cockpit and outside of it as well.

The Case for Case-Based Training. The self-directed learning philosophy need not be problem-based. It is important to review from a cognitive and methodological perspective, why case-based (nee: problem-based) teaching methods are likely to be effective in meeting the goal of fostering *expertise* in an accelerated time frame within the CC-130 training program. Here is why knowledge is better transformed into operational skill using cases.

Formal conversion training is often designed such that operators receive a level of training necessary to produce 'competent' performance, that is, a performance level sufficient to produce safe system operation [23]. At the end of formal conversion training, pilots can probably be best described as 'trained novices' [24] rather than as anything approaching experts. At this point their acquired knowledge is unlikely to be well-differentiated or well-integrated, characteristics classically associated with expertise. On a continuum that ranges from compartmentalised knowledge to integrated knowledge, the structure of the systems mental models held by trainees at this point in their training is likely to be classed towards the fractionated, or compartmentalised, end of the continuum. The training challenge presented by systems knowledge acquisition is, of course, to devise tools and methods of training delivery that will allow trainees to progress along this continuum of integration toward the more expert end — in the absence of real world experiences with all likely or unlikely systems situations.

With reference to specific kinds of knowledge to be trained, pilots will have three sorts of understandings represented in their developing mental models of aircraft systems at this point in their post-conversion course:

- declarative knowledge,
- procedural knowledge, and
- operational skill [25].

Declarative knowledge is the factual knowledge possessed about the system, things like its components, controls, and functions. Procedural knowledge refers to the rule-based knowledge possessed, such as how to operate the system and how to perform sub-component tasks. Operational skill is the ability to integrate the first two forms of knowledge, the declarative and the procedural, in a goal-directed, multi-task, time- and resource-constrained environment, in other

words, in the kind of dynamic decision making environment that the CC-130 flightdeck represents. It also includes executive function sorts of knowledge, such as recognising when activities are required (situational awareness, implicational thinking, prioritisation, etc.) and knowing how to co-ordinate these activities to meet the demands of real-time operations (e.g., pre-planning, managing time, allocating aircraft and team/human resources, etc.).

Expertise is most related to the last of these three knowledge contents — the operational application of knowledge in real time. Studies have demonstrated that operators matched on their declarative and procedural knowledge (as assessed by test scores), but differing in expertise, show marked differences in their operational performance effectiveness [26]. Trained novices typically exit from formal training with incomplete declarative knowledge and incomplete and only loosely integrated procedural knowledge, yielding a 'buggy' cognitive representation of each system [27].

Usually, expertise is obtained over time — through the accumulation of real world experiences that are integrated into the basic mental conceptual model. By experiencing a wide range of situations, acting to control systems within those situations, and receiving feedback about the results of control actions attempted, pilots' declarative and procedural knowledge becomes integrated into operational skill. Unfortunately, OJT sometimes does not expose all pilots to all pertinent situations, so that line flying accumulated over a period of time does not always build expertise sufficiently. In addition, after-action or after-event reviews may be missed [28], insufficiently detailed, or informal at the Squadron level, causing valuable training lessons to be foregone and learning opportunities to be lost.

Herein lies the great potential of a case-based self-directed training system for use primarily at OJT. By collecting and articulating in the form of case-based learning, a widely representative sample of typical actions and Standard Operating Procedures (SOPs), as well as known incidents, accidents, anomalies, and typical faults, one can with simulation and a repertoire of cases, approximate the breadth and depth of training that would normally occur over a more extended period of time. Encapsulating the organisation's knowledge in this way also serves to preserve its organisational memory of 'war stories' and 'hangar flying' —its informally archived cases.

Note that training success will depend in large measure upon the selection of appropriate training scenarios under a case-based approach. 'Appropriate' entails a choice of case scenarios that provides the proper environmental contexts and cues that reflect the way systems knowledge is actually used in that system's domain. If chosen or built wisely, the simulator cases will promote the integration of knowledge and enhance operational skill [29]. By trading cases with other fleets operating the C-130 airframe, an even fuller repertoire of situations can be represented.

Problem-Based Learning's Best (and Appropriate) Practices for OTU/OJT. It is recognised that 426 Squadron OTU currently employs a variant of a problem-based learning component in its use of case studies. A radical re-design of the training system, in favour of a completely problem-based approach, is not suggested. Chalk-and-talk lectures and other forms of teaching should continue to have their proper place in the methods of training or delivery used.

However, for the future, when such training challenges as the Avionics Update Programme arise, it is believed that the benefits of life-long learning and self-study via self-directed learning will become more necessary as mechanisms to help aircrew remain current in an increasingly systems knowledge-intense environment. While the role of the training instructor remains important and will not be diminished in this new scheme (in fact, it is enhanced and more appropriately deployed), students must be given better resources, skills, and the motivation for self-directed learning and self-paced study as an additional avenue toward continuous performance improvement. Further, they must be exposed to the kinds of group-based learning which mimic their work environments on the flight deck. Once the group-based format is acquired during ground school at 426, it will be easily recapitulated as a 'method of work' in the operational

environments at the squadrons. Moreover, it has great potential as a distance-based group method using suitable real time communication across computer networks, allowing teams to be composed from members at a distance — such as from different squadrons.

Certain, limited aspects of the problem-based learning approach described above, can be translated into training practices that will have a positive payoff for the Hercules pilot community. In fact, existing elements of the OTU's current lessons, structures and philosophy lend them naturally to a problem-based approach. Class sizes, for example, are already small, much in keeping with the 5-6 member groups recommended by most problem-based programs. Lessons are already designed that focus on systems failures, a good springboard for the problem-based mode. And a compendium of 'war stories' (although as yet undocumented) can also act as excellent grist for the problem-solving mill.

The 'limited aspects' of the approach, referred to above as appropriate areas for adoption, are summarised in the following list:

- it is not recommended that the entire training effort be converted to this format — lectures are still the most efficient mode of rapid information transfer (except for CBT) when this is what is required, for example in early learning;
- more study must be given as to which specific lessons are best delivered in the problem-based mode;
- implementation should be phased, and slow to moderate in speed;
- proper training in the method for trainees must be supplied — such training is essential in teaching requisite skills for problem-based learning and in setting expectations for training and self-efficacy — the latter factors have been shown to be instrumental in the effectiveness of training [16];
- proper training for trainers must be executed, enabling trainers to assume their new roles as facilitators, mentors, Subject Matter Expert (SME) models, resources for self-evaluation, etc.; and
- objective evaluations must be developed (subjective forms of evaluation, inappropriate to the military training context, are often used in applications of problem-based learning).

At present, the times, places, and choice of learning path used by the student are still largely in the hands of the training system. The results of problem-based learning approaches indicate that, within limits and with considerable guidance at times, trainees' learning is more effective when they have some control over these factors. Students learns best when they can identify their learning needs, select learning methods that suit them best, select the location (time and place) where learning is maximised, and learn to identify through appropriate unsolicited, and later requested, feedback, whether or not they are achieving their goals.

A suitable tool for self-paced study is needed that would allow such flexibility in the learning of systems knowledge and in the continual upgrading required to remain current on the complex systems contained in the CC-130 at present and in the future. The basics of such a self-study tool already exists in the form of the Smart Board system simulation interactive CD ROMs. While currently this tool is used primarily in the classroom at the OTU, it can be amended for use as a stand-alone self-directed learning resource made available at the Squadrons and for use at home. As its hardware requirements are currently within the abilities of most home PC systems on the market today (and in the future), and as the software upgrades to these packages needed to facilitate self-paced study do not require additional PC system capabilities, this tool has excellent self-directed learning potential.

To fully realise the learning potential of the Smart Board 'part task simulators', several ways in which this technology can be leveraged are suggested (see next sections), for example, by combining them with video re-creations of documented incidents/accidents and known problems, by adding an **A**wareness-**I**mplications-**P**lanning (AIP) overlay module to begin to explicitly teach AIP principles as habits of thought, and by adding some intelligent tutoring capabilities (see below).

Implications. To summarise, the addition of a problem-based learning focus in the OTU and beyond carries with it several implications:

- the requirement to train trainees in this method of work at OTU (initially at the conversion course or earlier for pipeliners), so that they may continue this form of education at OJT — this is critical to its success in the creation and effective management of work teams;
- the requirement to train the trainers in this method both at the OTU and at the operational units;
- the need to create self-paced study tools (via software extensions of Smart Board); and
- the need to create and manage a compendium of training cases.

Effective Use of Interactive Multi-Media for OTU/OJT and Self-Study

Recent trends in technical education point squarely to multi-media packages as a currently preferred major mechanism of course delivery. Efficacy studies show the reduced knowledge acquisition times and enhanced knowledge retention levels achievable via these packages, be they traditional computer based training (CBT) or low to mid-fidelity simulations [30, 31]. Another chief advantage of multi-media is its potential for self-study application outside the classroom.

Specific ways in which the Smart Boards may be leveraged to improve them even further are now reviewed. Following this, a recent development in intelligent tutoring is described — one that employs cases as method within a multi-media environment, in keeping with our emphasis on problem- or case-based teaching methods.

Improvements to the Smart Boards. Smart Board modules are excellent training aids, and early anecdotal evidence of their efficacy regarding learning speed and retention from 426 Squadron is extremely promising (personal correspondence). It is understood that their initial development was for the training of technicians, but it is believed that they can be even further enhanced to achieve the kind of pilot knowledge and skill acquisition objectives enumerated in this Volume. They should therefore be finished on a fast track for all systems not currently represented in this format, and appropriate applications should be developed for the conversion course, pilot upgrade to left seat course, and Flight Engineer's (FEs') course at the OTU, as well as for applications at the Squadron level. In the terms already discussed for effective, efficient, and evaluatable training, the Smart Boards lend themselves readily for application because:

- the schematics provide a visual conceptual scaffolding of the kind whose importance has been emphasised as the central learning objective for pilots at 426 Squadron;
- the Smart Board software is easy to distribute to Squadrons, hardware infrastructure notwithstanding — the full system dynamic representation in the 'lower' half of the display is an effective detail/skill developer that can be resourced repeatedly at the Squadron level to enhance the conceptual underpinning imparted at ground school and to integrate declarative and procedural knowledge into operational skill;

- with relatively simple enhancements, the AIP formulation can be integrated with current Smart Board representations (see next section) — the focus again will be on system implications and system interdependencies; and
- Smart Board feedback functionality can be incorporated anywhere along a continuum from non-intelligent interfaces (e.g., pop-up windows with verbal answers) to intelligent ones (e.g., intelligent tutors) — because an eventual goal is to allow self-directed learning, it is recommended that at least some measure of intelligence is put behind the tutoring system.

The potential for self-study using the Smart Board is obvious (see last point). Some direction will have to be given as to the appropriate (or standards-based) level at which the material is expected to be learned for a given crew position, but the potential for learning to whatever depth is desired by pilots should be preserved. The following improvements are recommended.

- Allow aircrew to interact with systems simulations: when illustrating cases, having a dynamic representation of aircraft systems in real time in the form of a Smart Board display, as well as a real-time video simulation of cockpit events (played on-screen eventually as hardware is upgraded, and via a parallel presentation medium initially), will be a powerful aid to training. The instructor should be able either to stipulate the end point of the dynamic system or to render ineffective certain student actions, so as to be able to simulate real aircraft cases of incidents and accidents where pilot control actions proved ineffective.
- Allow monitoring, evaluation and feedback of student actions: whether in-course or in self-study mode, the smart boards can be engineered to come equipped with 'canned' starting system parameters. By recording obvious indicators such as pilot control actions and their sequences, reaction times, and responses to open-ended queries (e.g., problem awareness and diagnosis, implications, pre-planning, knowledge of system interactions, etc.), instructors (or an intelligent tutor) can evaluate a student's systems knowledge. Such measures taken over time would allow tracking of student progress. Used as a formal evaluation method, normative data could be collected about fleet-wide trends using a non-jeopardy data base. Especially in self-study mode, feedback to the student can be given in a way that provides raw data for the development of meta-knowledge (knowledge about the state of one's knowledge), an important precursor of expertise and objective self-evaluation about proficiency in knowledge and habits of thought.

Intelligent Tutors for Simulation. It is encouraging to have recently found a training tool with many of the formal properties that have been reviewed above as being desirable best training practices. This tool was conceptualised independently of this review, but is convergent in its recommended methods for training delivery. It is reviewed now in some detail, noting at the outset a number of ways in which it is similar and number of ways in which it differs from the current proposals for renewed training delivery.

Chappell and Mitchell [27] recently described an architecture for a computer-based training system for operators of complex dynamic systems, the Case-Based Intelligent Tutoring System (CB-ITS). This can serve as a conceptual roadmap for leveraging the investments made to date by 8 Wing in the Smart Board systems knowledge delivery modules. It is similar to the approach recommended in this Volume, as follows:

- it is intended to help pilots enhance and maintain expertise;
- it is inherently case- or problem-based, providing users with normal as well as unusual operating situations;
- it emphasises the acquisition of sound conceptual underpinnings for systems knowledge — the 'how' and 'why' of systems functioning, not just the 'what';

- it includes a simulator that allows students to practice translating their procedural knowledge into operational skill;
- it includes an intelligent tutor with variable ability to provide intelligence and instructional control as a function of student needs; and
- it is inherently closed-loop and systems-based (e.g., in its use of feedback to the student to help null the error signals while learning).

Chappell and Mitchell's approach is different to the approach to instructional delivery recommended in this Volume, in the following ways:

- it is designed primarily as a self-directed form of OJT, whereas the approach recommended for the CC-130 would marry it to both OTU and OJT in terms of a common approach and method of work;
- it does not integrate an AIP framework (see next section);
- it does not integrate teamwork into the method of work;
- it has less emphasis on developing high level self monitoring skills and self-evaluation; and
- it uses a different simulation platform.

These points stated, the utility of intelligent tutoring systems (ITSs) lies in their ability to tailor instruction to the needs of individual students. To do so, such systems contain four components:

- a domain expert,
- a student model,
- the instructional method, and
- the tutor interface [32, 33].

The domain expert is a model representing knowledge that characterises expert performance, including declarative and procedural knowledge, and operational skill. The student model represents the tutor's changing knowledge of the student's knowledge. By comparing at any point the domain model with the student model, the tutor selects teaching strategies such as cases, illustrations, hints, coaching, etc., that will close this expert-student gap. Such contents are delivered via interaction with the student using the tutor interface.

An ITS is intrinsically closed loop or cybernetic in nature, in keeping with the overall theme we have struck regarding systems theory. In attempting to null the 'error signal' between student and expert, the ITS exerts control actions on the student. As a student becomes more advanced, the ITS exerts less control and models its expertise to a decreasing degree along a continuum ranging from active prompting, to providing feedback when it notes an error or anomaly, to minimal intervention (i.e., only providing updates on systems at checkpoints, when errors are no longer recoverable).

Collins [20] suggests that an ITS delivers a form of 'cognitive apprenticeship' to the student by demonstrating expert performance in the context of realistic task scenarios. In doing so it helps students to better integrate knowledge of systems and procedure into operational skill because the knowledge of systems required for safe and efficient flight performance that is illustrated occurs in a multi-task, real-time simulation. Cognitive apprenticeship has been used with some success in several training systems that teach performance and decision making in naturalistic decision making environments with complex systems [25, 34].

During simulation, CB-ITS allows students to make the implicit knowledge contained in its expert model explicit at any point in time. The student simply must ask why the steps in an activity may

have been prescribed by the tutor to receive reasons that describe the pertinent declarative and procedural knowledge and integrate it into the situation in progress. This too promotes the development of operational skill and perhaps meta-awareness of the state of one's knowledge as well.

Other expert systems offer similar capabilities, and may even allow better development of students' expertise and meta-knowledge. For example, the expert system knowledge elicitation package EXSYS prompts students with questions about the state of their knowledge [35]. During this process students may at any point ask why the question itself is being asked by the system. A tutor that describes why it is making queries, in the manner and order in which it is, can usefully model the expert's thinking process. The ability to reason about novel situations is a hallmark of expertise, and among the most important things to model and learn along the road to expert knowledge is the sequence of appropriate questions to ask. The implicit causal model of systems operations held by the expert that allows reasoning, a model that one would like to have students learn, is often well exposed by observing the expert's process of inquiry, that is, the processes for generating new knowledge.

In summary, several expert knowledge representation software simulation packages exist that can be usefully built into the Smart Board system. When incorporated as intelligent tutors, these have the potential to provide effective and efficient training via self-study.

Implications. Implied in the use of multi-media packages is that 8 Wing should formally evaluate their efficacy (as has been begun for the Smart Board software). Chief downsides of multi-media include, of course, the initial development costs where customisation is needed. Corporations are placing such materials on their intranets for distance education purposes and self-study, implying additional costs for IT positions to support it, authoring software and instructor training, course management software, etc. The integration of an intelligent tutor will require an initial phase of expertise extraction and system representation in the domain expert model built for each aircraft system.

Development of Superior Mental Models of Aircraft Systems

Pilots in the CBAG validation study fell down on systems knowledge in two ways: first, because they had trouble in the initial recognition or diagnosis of problems and solutions, or second, because they failed to adequately take into account and plan ahead for possible implications of the systems problems they encountered. By teaching as a mental heuristic the **A**wareness-**I**mplications-**P**lanning approach — namely, how to be more aware of developing system states, how to create a habit of thought to consider the future implications of the systems problems experienced, and how to pre-plan for various systems and inter-systems contingencies — pilots will come to routinise in their thinking the very kind of diagnostic abilities they most need to solve systems problems.

The longer term view of this approach is to state that it is consistent with the emphasis placed elsewhere (this report, see Volume 5) on the theme of cockpit decision making, especially on the part of ACs. In this case, AIP contributes to decision making about systems in particular, and about the entire mission, as systems problems are considered in light of the big picture.

Implications. One way to instil an AIP mental approach to systems considerations is to query pilots in mid-simulation about what they are thinking about the systems they are operating. This would require the capability for the instructor to stop the simulation to make the inquiry (or allow the pilot to record their thinking in response to a pop-up window query). As this might prove disruptive, an alternate tack is to make the AIP inquiry part of all after-action and post-flight reviews (including part-task and simulator training), and consider making it overtly manifest via

inclusion in training checklists, say during the take-off and approach briefs. At minimum, a simple extension of instructors' current case scenarios that would ask pilots about systems implications, both in the future and for other systems as new faults are encountered, would go far in making this higher order mental model checklist habitual.

Appropriate and valid objective assessment instruments and standards need to be developed that would make such implicational thinking and pre-planning activities subject to formal evaluation. Feedback will be needed to allow students to develop an awareness of their strengths and weaknesses in these higher order cognitive skills (especially in self-study mode), and the fleet can be monitored squadron-wide to index the development of such safety skills in the non-jeopardy database.

The Need for Evaluation at Three Levels

Consistent with the general approach and framework of control systems theory, students also need appropriate feedback in order to evaluate their progress and achieve learning (i.e., null the error signals they are receiving about whether their actions on the environment are perceived to move them toward their goals). Mechanisms for this are many. The need for evaluation to occur on at least three distinct levels has been identified, namely:

1. Trainee Self-Evaluation
2. OTU/OJT Formal Student Evaluation and Organisation-Wide Monitoring and Evaluation; and
3. Formal Efficacy Study

Trainee Self Evaluation. The development of meta-awareness is a main goal of self-evaluation. This refers to the developing ability of a student to think about their own learning — its completeness, strengths and weaknesses, habits of thought, barriers, etc. Only when a student is capable of diagnosing what they do not know, and is motivated to correct this deficiency, can they be said to be a self-directed learner. This kind of meta-awareness is a demonstrated correlate (and most likely, cause) of independent thinking and expertise. It must be explicitly modelled as a habit of thought by trainers instructed about its importance, and themselves taught how to articulate their tacit expertise.

OTU/OJT Student Evaluation and Organisation-Wide Monitoring. In preparation for documenting the efficacy of the suggested modifications to the training system in general (e.g., use of more problem-based teaching with cases) and the Smart Board modules in particular (use of cases, self-study, intelligent tutor, etc.), standards of training will need development and evaluations of student performance against those standards will have to be performed. Student evaluation in quantitative terms must be part of the revised training package, along with mechanisms for student feedback about performance. Tracking pilot performances in the area of systems knowledge

- to establish a baseline, and through time, at exit from the various pilot training courses at OTU, as well as
- via the creation of a no-jeopardy data base build on spot-testing at OJT or appropriately systems knowledge-intensive, event-based, full-motion simulator scenario tests delivered during continuance training,

will serve as mechanisms for individual and fleetwide evaluation, respectively, of systems knowledge proficiency.

Formal Efficacy Study. Finally, using the assessment instruments and standards developed for proficient systems knowledge for each system, a formal study of the efficacy of this training as compared to either:

1. a 'pre-improvement' baseline, or
2. another CC-130 training environment,

should be conducted. The first option is preferable empirically, and because the main mechanisms for the re-engineered course delivery are the case-based approach and the Smart Board technologies, these are the main avenues of potential improvement and therefore should be the main locus of evaluation. If their efficacy can be demonstrated, this will be powerful evidence for the teaching methods recommended. This training product can then be 'sold' to other CC-130 fleets world-wide and to the CF fleet-wide.

Implications. Again, if implemented at 8 Wing, self-evaluation training would require feedback to students and the attendant support for it, especially via 426 and Squadron training/standards experts as well as by appropriate software-based feedback. New standards will need to be developed for evaluation purposes (e.g., for AIP), and a fleet management system and no-jeopardy database to accumulate fleet wide information to track trends in systems knowledge community wide should be instituted. A formal efficacy study may require the co-operation of another C-130 fleet for comparative purposes.

RECOMMENDATIONS

In light of the best educational and training practices as enumerated in the six themes in the previous Section, and building on the considerable strengths of the current training system, the following recommendations for systems knowledge training improvements for Phase III of this project are made. These have been made in light of the constraints of staffing complements, fiscal restraint, organisational restructuring, and existing computer hardware and software infrastructures, and reflect, it is believed, realistic goals.

1. Distribute more formal training to the Squadrons. Strong conceptual foundations in aircraft systems should be an increased focus of training to compensate for experience loss, and are most appropriately conveyed during the limited exposures pilots get to 426 Squadron (rather than an over-emphasis on detail in that venue). Convey more of the detail at Squadron, where knowledge becomes skill, and do so more regularly and formally via scheduled training, evaluation, etc. The overall plan should be orchestrated by 426, in consultation with Squadrons after an assessment of their needs. An increased role for OJT may imply more training of Standards Officers in educational theory, use of case-based instruction, computer literacy, methods of evaluation, etc. However, the results of this process will be that Squadrons will have more of a voice in creating the kind of operations-specific training of systems knowledge they require on the line, and will 'own' the training to a greater degree.

2. Use more case-based teaching, supported by video simulations of good as well as poor systems handling. Case-based teaching is both efficacious and enjoyable. It can be further enhanced in two ways. First, it may be paired with video simulations of real aircraft incidents/accidents, as well as illustrations of best practices. The videos would be created using incident/accident/best practices transcripts as a basis and using role-playing reservists or retirees as actors. This would require use of the full-motion simulator for videotaping (using typically the E and F sessions of the training programme). Second, cases can be embedded within the Smart Board presentation and learning format with or without accompanying video simulations. One focus of the case-based systems knowledge teaching units would be to illustrate system interdependencies — and the need for implicational thinking and pre-planning to deal with these. Given the high costs associated with linking the dynamic systems portrayed in the Smart Board modules, this is the most effective and cost-efficient approach to teaching causal inter-linkage between aircraft systems. In order to overcome a main obstacle to case-based teaching, the lack of suitably developed cases, it is recommended that training partners in the world-wide CC-130 community be found that would agree to share their cases.

3. Leverage the Smart Board software pieces. Deploy the Smart Boards at both the OTU and OJT within the context of both problem-based learning and self-study. Combine them with a case-based method of instruction, and intelligent tutoring for self-directed, continuous performance improvement. Build the tutors to provide feedback and develop pilots' abilities for objective, independent self-evaluation of the state of their systems' knowledge.

4. Teach the AIP model as a conceptual approach, at an early stage and throughout training so that it becomes habitual.

5. Conduct formal evaluation studies to document the efficacy of these value-added improvements.

Recommendations for Implementation

Systems knowledge training will be multi-stage, involving both 426 and Squadron-based training and instruction. It should incorporate:

- formal training opportunities;
- strong conceptual mental model building;
- adequate practice opportunities for the development of skill (including dynamic decision making with respect to systems wherever possible in simulations, part-task trainers, etc.);
- case-based learning;
- exposure to experts;
- self-study training; and
- feedback, reinforcement, and evaluation for the student.

Details of the implementation should be worked out with 8 Wing and 426 Squadron. The following tasks will need to be considered to complete the full implementation:

- determining the needed staffing complement at 426;
- determining the staffing and support needed at Squadron;
- an organisational analysis of the co-ordination needed between 426 trainers and Standards Officers at Squadron;
- a training needs analysis that stipulates the skills demonstrable at proficiency for each aircraft system;
- a training needs analysis that views each system in the context of its operational environment, for tailored systems training at Squadron;
- an evaluation of how much detail needs to be imparted at 426 vice Squadrons;
- determining the needed level of computer literacy for students and trainers, and delivering this training;
- training the trainers/Squadron officers in recent advances in case-based teaching theory and their roles as facilitators;
- determining how to make self-study packages accessible to students (e.g., via extended 426 hours, inter/intra net access, etc.);
- completion of all deliverables (courseware, caseware, etc.); and
- a formal efficacy study of the training.

CONCLUSIONS

Despite downsizing, and corporate raiding of its pilots, 1 CAD, through its OTU and OJT, continues to deliver a quality training product in the area of systems knowledge acquisition, and continues to provide innovative approaches (e.g. Smart Board Systems) to training. However, when compared to other fleets, and reviewed in terms of the education and training literature, systems knowledge training is in need of modernisation in terms of both effectiveness and efficiency of training philosophy, materials, methods, and evaluation.

Modernisation of systems knowledge training is especially important in the current context of lowered experience levels, as a compensatory defence against latent failures that otherwise would be caused by insufficiently prepared pilots or inadequately rigorous training regimes within the line management system. Modernisation of systems knowledge training methods is also timely in light of:

- training advances made for training semi-glass and cockpit flightdecks;
- the impending conversion of the CC-130 fleet to the semi-glass cockpit; and
- the identification (both in the aviation community in general, and within the CF CC-130 community in particular) of training for systems knowledge complexity as a major challenge for aircraft so equipped.

Modernised systems knowledge training will need to be:

- multi-staged and progressive;
- distributed more to OJT for improved integrated skill development;
- problem-, or case-, based;
- retooled to add higher order cognitive functioning with regard to systems (e.g., systems situational awareness, implicational thinking regarding systems problems, and planning for system and inter-system contingencies);
- career-long via self-study opportunities, which include the development of self-evaluation skills based on meta-knowledge (i.e., appraising what you know, realistically knowing what you don't know, and identifying what you need to know);
- based on efficient training tools such as interactive multi-media simulations incorporating performance feedback; and
- evaluated in the formal terms of an efficacy study.

Fleet-wide efficacy of the training over time, as well as long-term trends in absolute levels of systems knowledge fleet-wide, should be monitored via a no-jeopardy database of systems knowledge evaluations collected from several sources:

- from systems knowledge performance evaluated on exit from the Conversion and left seat upgrade course;
- from systems knowledge performance in appropriately designed, event-based scenarios given during continuation training simulator sessions (i.e., scenarios that incorporate systems knowledge demands); and
- in terms of reported incidents and accidents involving poor systems knowledge.

Implementation of the systems knowledge training proposed in this Volume will require an investment in:

- the Smart Boards System as the corner-stone training tool;
- leveraging those CDs to even greater educational benefit (e.g., by adding the AIP — Awareness, Implications, and Pre-planning — heuristic, self-study, generation of a library of training/simulation cases, use of simulation in concert with video re-enactments, development of intelligent tutors for self-study, etc.);
- hardware and software infrastructure improvements at OJT;
- training both trainers (OTU and OJT) and trainees in the methods of case-based instruction;
- additional training personnel assigned to the OTU to oversee the improvements, modernisation, and direction of the OJT portion of the training; and
- general IT and computer training support.

Key benefits of the recommended systems knowledge training modernisation are:

- increased **safety**;
- increased operational efficiency; and
- a potentially saleable training package (i.e., philosophy, structure, tools, evaluation, etc.) to the C-130 community world-wide, and to the CF fleet-wide.

REFERENCES

1. Hendy, K.C., Thompson, M.M., Fraser, W.D., Jamieson, D.W., Comeau, P., Mack, C.I., Paul, M.A., and Brooks, C.J. (1998). Human factors of CC-130 operations — Volume 1: Final report of the DCIEM/ATG study team (DCIEM 98-R-14). Toronto, Ontario, Canada: Defence and Civil Institute of Environmental Medicine.

2. Thompson, M.M. (1998). Human factors of CC-130 operations — Volume 2: Crew performance measures (DCIEM 98-R-15). Toronto, Ontario, Canada: Defence and Civil Institute of Environmental Medicine.

3. Fraser, W.D. (1998). Human factors of CC-130 operations — Volume 3: Future aircraft performance measures (DCIEM 98-R-16). Toronto, Ontario, Canada: Defence and Civil Institute of Environmental Medicine.

4. Hendy, K.C. and Ho, G. (1998). Human factors of CC-130 operations — Volume 5: Human factors in decision making (DCIEM 98-R-18). Toronto, Ontario, Canada: Defence and Civil Institute of Environmental Medicine.

5. Paul, M.A. and Pigeau, R.A., Weinberg H. (1998). Human factors of CC-130 operations — Volume 6: Fatigue in long-haul re-supply missions (DCIEM 98-R-19). Toronto, Ontario, Canada: Defence and Civil Institute of Environmental Medicine.

6. Banks, R.D., Hendy, K.C., Fraser, W.D., Thompson, M.M., Jamieson, D., Wright, H., Gee, T., Mack, C.I., Latulip, J., Davis, B., and Cole, M. (1996). Human factors study of CC-130 operations (DCIEM 96-R-66). North York, Ontario, Canada: Defence and Civil Institute of Environmental Medicine.

7. Reason, J. (1990). *Human Error*. New York, USA: Cambridge University Press.

8. Thompson, M.M., Jamieson, D.W., and Hendy, K.C. (1997). Assessing mental model content and function: A metric of effective crew performance. In, R.S. Jensen and L.A. Rakovan (Eds.), *Proceedings of the 9th International Symposium on Aviation Psychology*. Columbus, OH, USA: The Aviation Psychology Laboratory, The Ohio State University. (in press).

9. Hendy, K.C., Liao, J., and Milgram, P. (1997). Combining time and intensity effects in assessing operator information processing load. *Human Factors*, 39(1), 30-47.

10. Kantowitz, B.H. and Campbell, J.L. (1996). Pilot workload and flightdeck automation. In, R. Parasuraman and M. Mouloua (Eds.), *Automation and Human Performance: Theory and Application*. Mahwah, NJ, USA: Erlbaum. 117-136.

11. Hypher, R.P. (1983). Analysis and critical appraisal of CC130 conversion training, OJT, and upgrading (ATGOR Staff Note). CFB Trenton, Astra, ON, Canada: Operational Research Branch, Air Transport Group Headquarters.

12. Hypher, R.P. (1990). Study into modernization of CC130 Hercules pilot training methods at the operational training unit, on-the-job training and upgrading . Ottawa, ON, Canada: Operational Research and Analysis Establishment.

13. Casner, S.M. (1995). Laptop applies new concepts in computer-based learning to flight deck automation training. *ICAO Journal*(May), 18-19.

14. Anon. (1997). Introduction. In, *Proceedings of the Second Global Conference on Lifelong Learning*. Ottawa, Canada: The Canadian Alliance for Lifelong Learning.

15. Pallie, W. and Carr, D.H. (1987). The McMaster medical education philosophy in theory, practice, and historical perspective. *Medical Teacher*, 9(1), 59-70.

16. Cannon-Bowers, J.A., Salas, E., Tannenbaum, S.I., and Mathieu, J.E. (1995). Toward theoretically based principles of training effectiveness: A model and initial empirical investigation. *Military Psychology*, 7(3), 141-164.

17. Barrows, H.S. and Tamblyn, R. (1980). Problem-based learning: An approach to medical education. In, S. Jonas (Ed.), *Springer Series on Medical Education*. Berlin, West Germany: Springer-Verlag.

18. Harrison, R. (1977). Self-directed learning: A radical approach to educational design. *Simulation and Games*, 8(1), 73-94.

19. Kolodner, J. (1993). *Case-Based Reasoning*. San Mateo, CA, USA: Morgan Kaufmann.

20. Collins, A. (1991). Cognitive apprenticeship and instructional technology. In, L. Idol and B.F. Jones (Eds.), *Educational Values and Cognitive Instruction*. Hillsdale, NJ, USA: Erlbaum. 121-138.

21. Anderson, P. and Henley, I. (1995). Assessing the development of team skills using a time-limited exercise. In, R.S. Jensen and L.A. Rakovan (Eds.), *Proceedings of the 8th International Symposium on Aviation Psychology*. Columbus, OH, USA: The Aviation Psychology Laboratory, The Ohio State University. 625-630.

22. Herman, R. (1983). Intervening in groups: A repertoire and language of group skills for self-directed learning in decision-making groups. *Small Group Behavior*, 14(4), 445-464.

23. Billings, C.E. (1997). *Aviation Automation: The Search for a Human Centered Approach*. Mahwah, NJ, USA: Erlbaum.

24. Chappell, A.R. and Mitchell, C.M. (1997). Intelligent tutoring systems for 'trained novices': Building expertise in mode management. In, R.S. Jensen and L.A. Rakovan (Eds.), *Proceeding of the 9th International Symposium on Aviation Psychology*. Columbus, OH, USA: The Aviation Psychology Laboratory, The Ohio State University. (in press).

25. Chu, R.W., Mitchell, C.M., and Jones, P.M. (1995). Using the operator function model and OFMspert as the basis for an intelligent tutoring system: Towards the tutor/aid paradigm for operators of supervisory control systems. *IEEE Transactions on Systems, Man, and Cybernetics*, SMC-25(7), 1054-1075.

26. Stokes, A.F., Kemper, K., and Kite, K. (1997). Aeronautical decision making, cue recognition and expertise under time pressure. In, C.E. Zsambok and G. Klein (Eds.),

Naturalistic Decision Making. Mahwah, NJ, USA: Erlbaum. 183-196.

27. Chappell, A.R. and Mitchell, C.M. (1997). The case-based intelligent tutoring system: An architecture for developing and maintaining operator expertise. In, *Proceedings of the 1997 IEEE International Conference on Systems, Man, and Cybernetics*. Orlando, FL, USA: (in press).

28. Hughes, R.C. (1996). The after review process: A heuristic computer assisted tool for training. In, *Proceedings of the Society for Applied Learning Technology Conference, Interactive Multimedia '96*. Washington, DC, USA: Society for Applied Learning Technology. (in press).

29. Cannon-Bowers, J.A. and Bell, H.H. (1997). Training decision makers for complex environments: Implications of the naturalistic decision making perspective. In, C.E. Zsambok and G. Klein (Eds.), *Naturalistic Decision Making*. Mahway, NJ, USA: Erlbaum. 99-110.

30. Bahlis, J. and Corneau, D. (1994). Case study: Development and implementation of interactive self-study training program at National Defence Headquarters, Directorate of Civilian Training and Development. In, *Proceedings of the Society for Applied Learning Technology Conference, Interactive Multimedia '94*. Washington, DC, USA: Society for Applied Learning Technology.

31. Miller, R.L. (1990). Learning benefits of interactive technologies. *Videodisk Monitor*(February), 15-17.

32. Burns, H. and Capps, C.G. (1988). Foundations of intelligent tutoring systems: An introduction. In, M.C. Polson and J.J. Richardson (Eds.), *Foundations of Intelligent Tutoring Systems*. Hillsdale, NJ, USA: Erlbaum. 1-20.

33. Wenger, E. (1987). *Artificial Intelligence and Tutoring Systems: Computational and Cognitive Approaches to the Communication of Knowledge*. Los Altos, CA, USA: Morgan Kaufmann.

34. Lajoie, S.P. and Lesgold, A. (1989). Apprenticeship training in the workplace: Computer coached practice environments as a new form of apprenticeship. *Man-Machine Mediated Learning*, 3, 7-28.

35. Huntington, D. and Awad, E.M. (1997). On-line dissemination of expert knowledge on the web. In, *Proceedings of the Society for Applied Learning Technology Conference, Interactive Multimedia '97*. Washington, DC, USA: Society for Applied Learning Technology. (in press).

ACKNOWLEDGEMENTS

The work described in this volume was performed by Psychotechnic Solutions, Burlington, under Public Works and Government Services contract W7711-5-7264 for the Defence and Civil Institute of Environmental Medicine. The Scientific Authority was Mr. Keith Hendy of the Human Engineering Sector.

I would like to thank the training staff of 426 Squadron, 8 Wing, CFB Trenton, for providing to me courseware and training resources/reports for review, for the many patient explanations and demonstrations given to me about their training philosophy, development, and methods, and for the courtesy and professionalism extended to me by them in all our interactions. I would also like to thank Dr. Megan Thompson for her support, and my Chief Scientific Officer and project leader, Keith Hendy, for his insights, support and guidance in the execution of the contract and in the preparation of this report.

APPENDIX 1: LISTING OF RESOURCES

RESOURCES

The following resources have been assembled from a variety of sources. Most are brief descriptions culled from the Proceeding of the Society for Applied Learning Technologies' (SALT) annual conference entitled, *Interactive Multimedia '96*, which was held from August 21 to 23, 1996 in Washington, DC and attended by the author. A copy of these proceedings is held at DCIEM.

LIFELONG LEARNING RESOURCES

Contact: The Canadian Alliance for Lifelong Learning (CALL)
Suite 400, 20 Bay Street,
Toronto, ON
M5J 2W1

Telephone: (416) 325-4211
Fax: (416) 325-4675

e-mail: CALL@gsro.carlton.ca
Web: http://gcll.carlton.ca

CALL is a non-profit organisation committed to developing an action plan for lifelong learning in Canada and around the globe. It is associated with similar organisations around the world through its membership in the World Initiative in Lifelong Learning, based in Brussels.

One of the major foci of this alliance is on practical issues involved in the implementation of learner-centred environments, methodologies, technologies, and social strategies. They keep a case-study catalogue of actual examples of workplace models of continuous learning, geared to the application of the newest technology or the newest learning models, such as learning organisations, self-directed learning, learning via the Internet, the electronic classroom, distance education, etc.

Because the lifelong learning philosophy and methods such as problem-based learning are now being applied down to the kindergarten level, they span all age ranges in education. However, there is a particular focus within this span on adult education in general (e.g., within human resources development on productivity improvement strategies based on continuous learning and career planning) and on workplace training in particular (e.g., creating and sustaining learning environments within government/industry environments; impact of new technologies; electronic classrooms; etc.).

Self-Directed Learning Resources

Title: The McMaster Medical Education Philosophy

Contact: Health Science Centre
Faculty of Health Sciences
McMaster University
1200 Main Street West
Hamilton, ON
L8N 3Z5

Telephone: (905) 525-9140

Since its inception in 1969, McMaster University's Health Science Centre has pioneered radical innovations in medical education. With nearly 30 years experience in the student-centred, problem-based, self- and group-directed learning philosophy, it stands as an excellent Canadian resource for the introduction of effective new methods in the lifelong learning field. Widely copied both within medicine (e.g., Harvard Medical School) and without (all other McMaster faculties), it is a respected source of information. McMaster holds a week-long, biannual visitor's workshop which serves as a briefing programme to its methods.

Conference on Interactive Multimedia '96

This conference was sponsored by the Society for Applied Learning Technologies (SALT). Section headings reflect particular themes. The following presentations are noteworthy.

Performance Support System Rescues

Title: Use of the Internet to Assist in Creating CBT, Performance Support And Interactive Learning Programs

Author: *John Kellum*, VP and GM of Multimedia Tools, Asymetrix Corp.

How to create quick, easy, cost-effective CBT, PSS, and interactive learning applications. Supplied internal education to Boeing.

Title: How to Design and Build User-Centred Integrated Training and Performance Support System

Authors: *Janis A. Morariu*, Peak Potential, Inc. and *Eric J. Malecki*, M Multimedia, Ltd.

Describes their Integrated Training and Performance Support (ITPS) Design Methodology, which includes 5 types of goals/requirements and proceeds through five stages. Case study example is the FAA's Training and Evaluation Support System (TESS), developed according to the methodology, as the FAA's prototype model for determining training cost-benefits and Return on Investment (ROI).

Title: Performance Web[SM] Case Studies: How Training Organizations Are Using the World Wide Web

Author: *Michael Gallagher*, Director, Sales and Marketing, AERA, Inc.

Application of browsers to presentation of technical documentation and training via intranets. Case studies include NASA Goddard.

Special Design Resources

Title: Incorporating Cognitive Strategies and Metacognition into Interactive CBT

Author: *Anne-Marie Armstrong*, Instructional Designer, AERA

Provides a guide to designing screens that meet cognitive learning objectives, as well as evaluation of such objectives.

Title: Work Breakdown Structures (WBS): An Automated Systems Approach To Planning Technical Training

Author: *Darrell Tatro*, Program Coordinator, AEGIS Training Center, and *Marilyn, B. Newman*, Training Specialist, AEGIS Training Center

Aid to planning and implementing large-scale training programs; can be used as a methodology for planning overall training strategy, and multimedia training/tools within this strategy.

World Wide Web Training Resources

Title: Internet Access for Beginners (CD-ROM)

Authors: *Mary E. Sand*, Program Manager, Technical Training, FAA, and *Nicholas Chandler*, Director of Training Systems, New Media Division, SAIC

A CBI course that teaches and uses the skills needed to distribute and maintain text-based and other media-based teaching/learning products over the Internet (including CBI multi-media materials). The course teaches beginning Internet skills so as to avoid user frustration, time wastage, etc., while also serving as an introduction to CBT-based education and training.

Title: Training on the World Wide Web: Alternatives in Design and Development

Authors: *Ann Barron*, Associate Professor, Instructional Technology, University of South Florida, *Brendan Tompkins*, Programmer, and *Kord Kutchines*, Programmer, Analysis and Technology, Inc.

Presents new authoring tools, programming languages for interactive courseware creation, including HTML, Java, Shockwave, IconAuthor and PERL. Design guidelines are enumerated as well.

Title: How to Create Your Own Internet-Based Training Course

Author: *Pardner Wynn*, President, Stanford Testing Systems, Inc.

Demonstration of how to create a complete Internet-Based Training (IBT) course using IBTauthor, an off-the-shelf authoring tool.

Title: US Department of Defense On-Line Internet Journal for Training and Performance

Authors: *Leslye O. Fuller*, Instructional Technologist, Defense Business Management University, *Bart Morrison*, Senior Analyst, Analysis and Technology, Inc., and *Thomas J. Edwards*, Combined Arms Support Command, US Army

On-Line journal mounted to leverage the shared experience of US forces' application of technology to education and training. Idea exchange via usegroups, topical forums, downloadable journal articles, demonstrations of new technology, etc. Topic areas include human factors, cognition, CBT, intelligent tutors, simulation, distance education, adult education, multimedia, training devices, etc.

Title: Internet Treasures for Trainers

Author: *Jodi Bollaert*, Instructional Technologist, Ford Motor Company

Listing of web sites, gophers, and newsgroups for training specialists.

Title: Air Force Distance Training

Author: *Thomas E. Wolfe*, Chief of Distance Learning Instructional Design Branch, Air Force Distance Learning Office

Covers the expansive growth of distance learning in the USAF with CBI, interactive courseware, and interactive multimedia. Exhaustive coverage suitable to an audience from beginners to practitioners, dealing with intranets to MBONE.

Multimedia Development Resources

Title: Storyboarding That Really Supports Multimedia Development

Authors: *Gary E. Davis*, Multimedia Development Specialist; Lucent Technologies, and *Robert C. Fratini*, Senior Advanced Media Consultant, AT&T Network Systems; Lucent Technologies

Lesson planning for case study presentation via multimedia can be done easily by storyboarding. This paper describes the organisational factors needed to support successful storyboarding, as well the Multimedia Information Modeler to be used by the SME in lesson planning for multimedia.

Title: The Power of Interactive Video for FAA Course Development and Delivery: Lessons Learned

Author: *Phyllis Peters Marson*, FAA

Paper on interactive video training in the FAA. Only marginally relevant, but included here should the interactive teleconferencing of course delivery ever be considered.

Title: Interactive Multimedia Learning Systems

Author: *Michael Dulworth*, Insync Corp.

A good primer of multimedia learning systems, including how learning theory applies, the development process, and authoring systems. Includes a brief description of the four levels of multimedia learning: from customised linear presentation, to instructor-led/non-linear presentation, to facilitator-led training, to self-paced training.

Title: Rapid Scripting -- A Non-Traditional Approach to Storyboard Development

Author: *Mary F. Bratton-Jeffery*, US Navy

Current trends in authoring packages. Rapid scripting was developed to go beyond paper and pencil development tools and produce synergistic effects among interactive courseware production team members.

Training and Development Resources

Title: The After Action Review Process: A Heuristic Computer Assisted Tool For Training

Author: *Robert C. Hughes*, Program Manager, Cubic Applications

After Action Review (AAR) is a computer-assisted process designed to provide feedback after computer-assisted training, and to evaluate decision-making, courses of actions selected, performance against objectives and team interactions. The process promotes metacognitive development and awareness of the epistemology of what people are actually doing, and is highly compatible with the systems approach to training and education we have proposed. A meiotic teaching approach, it is based on Bloom's taxonomy of educational objectives and the metaphor of "candling", that is, observing without disturbing the group and learning process. R. Hughes is a former professor in the US Air Force Academy.

Title: Interactive Multimedia: Cost Benefit Analysis Issues

Author: *John J. Hirschbuhl*, Assistant to the President, Information Services, The University of Akron

Illustration by case studies of cost-benefit analysis and positive ROI for networked multimedia in corporate environments. Surprising results have been achieved. For example, the US Institute for

Defense Analysis, IBM, and American Airlines indicate that "computer-based multimedia produced a savings of 68% over conventional classroom training" (p. 4).

Innovative Technologies

Title: Automated Speech Technologies: Implications for Training and Education

Authors: *Lyn Gubser*, President, American Insights, Inc., and *Thomas H. Held*, Director Multimedia, Marketing and Product Development, Cubic Applications, Inc.

Review of work at leading laboratories in language instruction and translation, natural language recognition systems and text-to-speech (TTS) systems. Describes the state of the art in Automated Speech Technologies (AST). This is potentially useful in transcription of verbal protocols in full motion simulator sessions testing systems knowledge.

Title: On-Line Dissemination of Expert Knowledge on the Web

Authors: *Dustin Huntington*, EXSYS Inc., and *Elias M. Awad*, McIntire School of Commerce, University of Virginia

Leading expert systems company EXSYS presents their approach to capturing and making accessible, expert knowledge. The system asks the user focused relevant questions and comes to conclusions about the state if their knowledge based on the answers. Users are allowed to ask questions in order to expose the knowledge and inference structures of the expert knowledge representation. Provides explanation and recommendations. Expert knowledge is built using expert knowledge development tools that are files containing decision-making knowledge expressed as rules or facts.

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g., Establishment sponsoring a contractor's report, or tasking agency, are entered in section 12.)
DCIEM
PO Box 2000 North York, ON
CANADA

2. DOCUMENT SECURITY CLASSIFICATION (overall security classification of the document including special warning terms if applicable)
Unclassified

3. DOCUMENT TITLE (the complete document title as indicated on the title page. Its classification should be indicated be the appropriate abbreviation (S,C,R or U) in parentheses after the title.)
Human factors of CC-130 operations. Volume 4: Training systems knowledge (U)

4. DESCRIPTIVE NOTES (the category of the document, e.g., technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)
Final Report

5. AUTHOR(S) (Last name, first name, middle initial. If military, show rank, e.g. Burns, Maj. Frank E.)
Jamieson, David W.

6. DOCUMENT DATE (month and year of publication of document)	7.a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.)	7.b. NO. OF REFS. (total cited in document)
December 1997	44	30

8.a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant)	8.b. CONTRACT NO. (if appropriate, the applicable number under which the document was written)
Project 3fa11	PW&GS W7711-5-7264

9.a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.)	9.b. OTHER DOCUMENT NO.(S) (any other numbers which may be assigned this document either by the originator or by the sponsor.)
DCIEM No. 98-R-17	

10. DOCUMENT AVAILABILITY (any limitation on further dissemination of the document, other than those imposed by security classification)

X	Unlimited distribution
	Distribution limited to defence departments and defence contractors; further distribution only as approved
	Distribution limited to defence departments and Canadian defence contractors; further distribution only as approved
	Distribution limited to government departments and agencies; further distribution only as approved
	Distribution limited to defence departments; further distribution only as approved
	Other

11. ANNOUNCEMENT AVAILABILITY (any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (10.) However, where further distribution (beyond the audience specified in 10) is possible, a wider announcement audience may be selected.)
Unlimited

12. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address.)
DCIEM
PO Box 2000, North York, ON
CANADA

DSIS DCD03
HFD 09/94

13. ABSTRACT (a brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual).

In January 1994, the Defence and Civil Institute of Environmental Medicine (DCIEM) was tasked by Air Command (AIRCOM) to study human factors issues in CC-130 *Hercules* operations within what was then Air Transport Group (ATG) — now a component of 1 Canadian Air Division. This tasking reflected a perception that the accident record within the Canadian Forces (CF) fleet was significantly worse than the record of other fleets involved in similar operations. In response to this tasking, a joint DCIEM/ATG team was formed. The activities of this study group were funded by the Chief of Research and Development (CRAD).

The following recommendation, served as the impetus to the work.

- Raise the overall level of systems knowledge among ATG aircrew by developing teaching aids and courses to accelerate the acquisition of knowledge and to compensate for lowered fleet experience levels through advances in training program delivery.

In this Volume, systems knowledge training is first placed within a general risk management scheme as an overall causal framework for securing safer and more effective operations within the CC-130 community of 1 Canadian Air Division (1 CAD). Current systems knowledge training practices within the organisation are reviewed next, including past assessments of the need for modernisation of training. It is concluded that while current training practices are sound, thorough, and professional in execution, there remains room for improvement because downsizing and experience loss have impeded the ability of 8 Wing, Trenton, to achieve training modernisation .

A selected review of best training concepts and practices is presented. The key areas covered include:

- the importance of life-long learning;
- a just-in-time knowledge-to-skill training model;
- problem-based (i.e., case-based), self-directed learning;
- effective use of interactive multi-media for training at the Operational Training Unit (OTU), for on-the-job training (OJT) and self-study;
- methods for the development of superior mental models of aircraft systems and their operational interdependencies; and
- the need for evaluation at three levels: trainee self-evaluation, OTU/OJT formal student evaluation, and organisation-wide monitoring and evaluation.

A set of recommendations is then presented, for value-added training system improvements in the area of aircraft systems knowledge acquisition. The Volume concludes with a summary of the deliverables, the implications for implementation that are discussed throughout, and the resource requirements implied by adoption of these recommendations.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible, keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

aviation safety
flight training
computer-based training

#508030

98-01222